leaves. The first-named has, as you know, large dark purple flower spikes of 2 feet long; the other, on the other hand, only short spikes with small white flowers. On these Coccolabas are found several nice Epidendrums.

The savannahs are frequent and extensive here, and afford a number of smaller plants of various descriptions.

In several parts of the island there are tracts of mahogany, which are cut for export.

The climate is generally cooler than in the smaller islands. I found the nights quite fresh. In the higher mountains, of course, it was quite cold at night. On the Pico del Valle I passed one night. We had a large fire blazing all night; in the morning, at 6 o'clock, the thermometer only showed 11° C.

Rivers and brooks are innumerable, but on account of the freshets and the violent current after rain, hardly any aquatic plants are seen, at least in this part of the island. I missed the beautiful *Pontedera* of Porto Rico.

I send you to-day, by mail, seeds of the only palm which I have been able to obtain, a species of *Euterpe*, which is common here above 1200 feet, and the fruit of which is much eaten by half-wild hogs. It is called "Manacla" here, and grows to a height of about 30 to 40 feet.

Towards the end of the year I propose continuing my explorations of the West Indies, having in view a further investigation of this island, especially of the east and south, and furthermore of the Bahamas (especially Andros) and the two islands of Tobago and Grenada, both of which, I believe, are very little explored. The northern part of Dominica is also still *terra incognita*, unless something has been done there since my visit in 1879 and 1880. This island is particularly interesting to me. I believe it is one of the most luxuriant of the West India Islands.

## CONSTITUTIONAL FORMULÆ AND THE PROGRESS OF ORGANIC CHEMISTRY.

IF the mere increase in the number of known facts were an accurate measure of the growth of a science, the question as to the progress of organic chemistry would be easily answered. Let the reader open a text-book on chemistry of fifty or sixty years ago, and he will find, sheltering itself under the wing of the inorganic chemistry of that day, the half-fledged science of organic chemistry. Then let him turn to Beilstein's gigantic *Handbuch der organischen Chemie*, with its more than two thousand large closely-printed pages—a mere classified catalogue of the known facts, written moreover in the highly-condensed elliptical style appropriate to catalogues. Here is increase.

But life is not measured by days, nor chemistry by new compounds; and the reader might resent the invitation to appraise the progress of organic chemistry by this rough quantitative method. A qualitative analysis is necessary here.

But how? The really important facts, even with the aid of the most judicious selection, could hardly be packed within the compass of a single article; nor would they be interesting, or, in such compression, even intelligible, to the non-chemist. There are of course the usual *pièces de résistance* in the shape of the coal-tar colours, and the various naturally-occurring compounds that have been artificially prepared; but probably the general reader has heard enough of these already, and might feel inclined to ask whether organic chemistry has nothing further to say for itself.

There is, however, a peculiarity of organic chemistry which distinguishes it from the remainder of the science. The aim of all chemistry is to ascertain the constitution of matter, and the said peculiarity of organic chemistry is, that it expresses its views on this important subject in greater detail, more precisely (or, as some will have it, more dogmatically), than inorganic chemistry. Its articles of belief on this head are embodied in its constitutional formulæ.

Here we touch on matter which every chemist will at once recognize as debatable. But, for good or for evil, these constitutional formulæ are, apart of course from the dry facts, the main scientific outcome of organic chemistry: they form the particular contribution which organic chemistry has been able to make towards solving the central problem of all chemistry—the constitution of matter. At present they crown the edifice of organic chemistry. Are they the keystone of an arch, or a mere meaningless architectural embellishment? This is the most general question which organic chemistry can put to itself at the present moment, and an attempt to answer it is the most fitting mode of reviewing the past work of the science. Let us therefore turn our attention to these constitutional formulæ, and ask ourselves what they are: what their meaning is, their scope, their justification.

According to some unfriendly critics, constitutional formulæ have done incalculable harm to chemistry by causing chemists to desert accurate experiment and observation for idle speculation—to substitute for the arduous work of the laboratory the easy task of stringing together atomic symbols, according to certain rules, on paper. There may in some cases have been some small measure of truth in this accusation—in other words, there may have been some occasional abuse of constitutional formulæ; but the injustice of the accusation as a whole is sufficiently proved by the fact that the most successful experimenters of the day in the domain of organic chemistry are enthusiastic supporters of constitutional formulæ, and confess to having been guided by these formulæ at almost every step of their researches. This actively-hostile attitude towards constitutional formulæ is fortunately becoming daily rarer.

Another class, not of detractors, but of rather lukewarm friends, of the constitutional formula, regard it as a convenient mnemonic device, by the aid of which the composition of otherwise hopelessly complex compounds may be successfully impressed on the memory. It is perfectly true that constitutional formulæ do perform this important function; but an impartial review of the case will, we imagine, lead to their being rated somewhat more highly than this.

A third class may be described as the undiscriminating admirers—the injudicious friends—of the constitutional formula. To them the constitutional formula is a final expression of the position of the atoms in the molecule—a picture of the molecule itself. This is a phase of belief which many pass through in making their first acquaintance with organic chemistry, and its existence is due to the circumstance either that the teacher is so much engrossed in impressing the complex array of facts and theories upon the mind of the student that he has not time to introduce philosophic limitations and doubts, or that he considers such an addition only calculated to render an already somewhat tough intellectual fare totally indigestible by a beginner. However this may be, it is certain that the faith of the beginner is quite as frequently appealed to as his reason.

We shall best be in a position to discern the meaning and to estimate the value of these constitutional formulæ, if we consider to what necessity they owe their origin, and how far they fulfil the purpose for which they were devised.

The atomic theory, as propounded by Dalton, satisfied for a time the requirements of chemists. For every properly-analyzed compound a more or less simple atomic proportion could be calculated, and this atomic proportion was expressed in the empirical formula of the compound. These empirical formulæ were combined into equations, and the equations formed a complete expression of the reactions, so far as the weights of matter taking part in them were concerned. Now it was experimentally proved that every definite compound possessed a constant qualitative and quantitative composition, and it seemed to chemists as something of the nature of an axiom that to a given composition one and only one compound could correspond. So convinced were they of the truth of this unproved and, as the event showed, totally erroneous proposition that, when in 1823 and 1824 the first cases of *isomerism*, or identity of composition together with diversity of properties, were discovered by Wöhler and Liebig, the results obtained by these eminent chemists were generally set down to faulty analysis. But the cases of isomerism multiplied rapidly, and chemists had to make their account with this altered state of things. But here the inadequacy of the empirical formulæ became evident. Wherever a case of isomerism occurred, the empirical formula was ambiguous, and the equations in which it was employed were neither a complete nor a precise expression of the reactions.

To some, the discovery that constancy of composition no longer involved constancy of properties may have seemed to sap the very foundations of chemistry as then understood. But this was not the case. The discovery necessitated an extension of the atomic theory, not its abolition. In fact, isomerism afforded a remarkable proof of the correctness of the view that matter consisted of atoms. On the alternative hypothesis that matter fills space continuously and homogeneously, isomerism is incapable of explanation; as it is inconceivable that the same given quantities of the same given kinds of matter, continuously and homogeneously filling space, should produce more than one compound. A difference of properties in such a case bespeaks a difference of *arrangement* of the component parts; and further, as each such compound displays, even in the state of the finest mechanical subdivision, perfect uniformity, the component parts, by the arrangement of which the difference of properties is produced, must be exceedingly small. We are thus led back to the atomic theory, whilst at the same time the extension is indicated which it was necessary to make in this theory in order that isomerism might find its proper place and explanation under it. It was necessary to determine, so far as possible, the *mode of arrangement* of the atoms in the various compounds. The results of this attempt are embodied in the constitutional formulæ which have been employed by chemists at various times.

The method resorted to in solving this problem was very similar to that which had been employed in determining the ultimate composition of compounds. Just as when, after isolating from a compound, or introducing into a compound, some particular kind of elementary matter, chemists concluded that the compound actually contained that particular kind of matter, so, when in a reaction a particular group of atoms was eliminated bodily from a compound, or introduced bodily into a compound, they concluded that this group existed as such in the compound. Unfortunately, the conclusion is not always quite so warrantable in the case of atomic groups as in the case of elements. The reaction, for example, by which an atomic group is eliminated from a compound involves the destruction of the parent compound, and in this process, which is generally more or less violent, it is only too easy for the atomic groups to undergo re-arrangement. In this way, alcohol ($C_2H_6O$), from the fact that it may be split up into ethylene ($C_2H_4$) and water ($H_2O$), was at one time regarded as containing these two atomic groups—a view which at all events is not that at present held. We thus see that from two different reactions, two totally distinct and mutually incompatible constitutional formulæ may be deduced for the same compound.

It would carry us too far to trace all the steps by which constitutional formulæ gradually became more precise and less self-contradictory, but a few important discoveries may be mentioned which have mainly tended to bring about this result. In the first place, the development of the idea of the molecule as distinct from that of the atom, and the discovery of a means of determining the molecular weight of bodies, led to the division of isomerides into two classes: those in which the proportions of the various atoms were the same, but the total number of atoms in the molecule was different—this mode of isomerism being distinguished as *polymerism;* and isomerism proper, in which both the proportions of the various atoms, and the total number in the molecule, are the same in the different compounds. But the knowledge of the molecular weight aided chiefly in the construction of constitutional formulæ by determining the exact number of atoms in the molecule, and thus facilitating the task of arranging these atoms by stating precisely how many atoms had to be arranged. The law of valency also exercised a most important influence, simplifying matters by greatly limiting the number of legitimate arrangements. In fact, in the case of some of the simpler compounds, such as methane ($CH_4$), ethane ($CH_3 . CH_3$), propane ($CH_3 . CH_2 . CH_3$), methyl alcohol ($CH_3 . OH$), and others, only one mode of arrangement is, according to the laws of valency, possible for each compound.

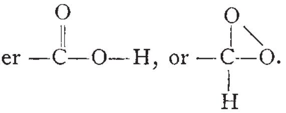
A modern constitutional formula, therefore, takes the various atoms of a compound in the proportions indicated by the empirical formula, and in the absolute number prescribed by the molecular weight, and arranges them in that way which, within the limits of the laws of valency, will best account for the reactions of the compound.

Let us consider what elements of uncertainty are involved in each of the various operations here enumerated.

The correctness of the empirical formula of a compound, as calculated from its percentage composition, depends upon the correctness of the atomic weights assigned to its component elements. In the case of organic compounds, to the consideration of which we shall confine ourselves here, the atomic weights of the component elements may be regarded as determined with a degree of probability approaching to absolute certainty. (This does not, of course, refer to the question whether the atomic weight of an element has been determined within 1/10,000 more or less of its true value, but whether, for example, in the case of carbon the atomic weight is 12, or some multiple or sub-multiple of 12.) The empirical formulæ of correctly analyzed organic compounds may therefore be regarded as standing on as sure a foundation as almost anything in the range of science which is a matter of deduction and not of direct observation or experiment. As regards the second point, the molecular weight, an almost equal certainty may be said to prevail in most cases in which the compound can exist in the state of vapour. Avogadro's law, that "when two gases or vapours are at the same temperature and under the same pressure, the number of molecules in unit of volume is the same in both gases or vapours"—this law, originally advanced as an hypothesis, has been shown to follow as a mathematical deduction from the kinetic theory of gases, a theory almost as well established at the present day as the atomic theory itself. Avogadro's law places in our hands a means of determining the molecular weight of substances which are capable of existing in the form of vapour, the only uncertainty attaching to its determinations being that occasioned by the tendency which many compounds exhibit, either to undergo decomposition, or to be incompletely vaporized, in passing into the gaseous state. But in the case of all compounds capable of existing undecomposed in the gaseous state throughout any considerable range of temperature, the molecular weight may be determined with a very high degree of probability. In cases where the compound is not volatile without decomposition, recourse must be had to indirect means in the determination of the molecular weight, and there is consequently more or less uncertainty in such determinations. As regards the third operation in the construction of a constitutional formula—the arrangement of the atoms so as to satisfy their valencies, and at the same time to account for the reactions of the compound in question—both parts of this process, but particularly the latter, involve more or less uncertainty. The valency of an element is frequently a variable quantity, and the validity of a constitutional formula for a compound will depend upon our attributing to each element the valency which it really possesses in that compound. In the case of organic compounds, however, this source of uncertainty is reduced to a minimum. Carbon is, with one certain and one or two doubtful exceptions, always a tetrad; hydrogen and oxygen are constant in their valency; and the character of nitrogen as a triad or as a pentad is generally easy to determine. The chief source of uncertainty lies in the difficulty of expressing the reactions of a compound by its constitutional formula, great scope being left here for arbitrary interpretation. To this is due the fact, on which the opponents of constitutional formulæ lay so much stress, that in the case of numerous compounds the accepted formulæ have varied from time to time. This could, however, scarcely be otherwise. A formula constructed on the basis of an insufficient number of reactions would have to be altered as soon as new reactions were discovered with which it was not in harmony. And it must be admitted that, in the case of most well-studied compounds, very few changes have been made in the constitutional formulæ since these were constructed on the principles of valency. In the case even of the more complex compounds, the constitutional formulæ show a tendency to become finally settled as soon as sufficient experimental material has been accumulated.

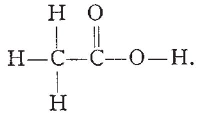
In this light, then, a constitutional formula is to be regarded as a symbolic expression, constructed according to the laws of valency, and embodying in a very condensed form the reactions of a compound. By a knowledge of the rules according to which such a formula is constructed—by a knowledge of chemical precedent, as it were—we ought, from an inspection of the formula, to be able to predict the reactions of the compound; to say beforehand, for example, how many substitution-products of a particular class a given compound ought to yield, and so on. The value of a good working hypothesis lies in the fact that it can predict: if it can predict nothing, it is worth nothing. Now, with regard to the question before us, we find that if we correctly embody in a constitutional formula a certain number of reactions—a number sufficient to warrant its construction—it will correctly predict an enormous number of reactions which were not in the least contemplated during its construction. Let us take the example of acetic acid:—

Starting with methyl iodide, which admits of only one constitutional formula, we convert it into methyl cyanide by heating it with potassium cyanide, $CH_3I + KCN = CH_3(CN) + KI$, thus substituting a monad group, CN, for the monad iodine atom. The constitution of this methyl cyanide is, however, not rendered clear by this reaction: it might be either $CH_3.CN$ or $CH_3.NC$ according as the cyanogen group is united to the carbon of the methyl by means of carbon or by means of the nitrogen. Both these compounds are in fact known. The one formed in the foregoing reaction has the first of these two constitutions, inasmuch as, when heated with acids or alkalies, it parts with its nitrogen in the form of ammonia, yielding acetic acid, $CH_3.CN + 2H_2O = CH_3.COOH + NH_3$. In this *hydrolysis*, or decomposition of the compound with assumption of the elements of water, the nitrogen atom of the cyanogen group is removed, whilst the carbon atom remains in combination; and we therefore conclude that it was by means of this carbon atom, and not by means of the nitrogen atom, that the CN-group was united to the carbon of the methyl group—a conclusion confirmed by the behaviour of the isomeric methyl cyanide, in which the carbon atom of the NC-group can be eliminated, leaving the nitrogen attached to methyl. The only question remaining to be solved is the constitution of the monad group, COOH, which might be either



$$-\overset{\overset{O}{\|}}{C}-O-H, \text{ or } -\overset{\overset{O\;\diagdown}{|}}{\underset{\underset{H}{|}}{C}}-O.$$

From what is known from other sources concerning the mechanism of the process of hydrolysis, the first formula is the more probable; that it is correct is shown by the behaviour of acetic acid towards the trichloride of phosphorus, by which reagent the hydroxyl group (OH) can be removed and replaced by a monad chlorine atom, whilst the resulting acetyl chloride ($CH_3.COCl$) may be reconverted by the action of water into acetic acid ($CH_3.CO.OH$). Acetic acid therefore contains a monad group, OH, exchangeable for chlorine; and the first formula is correct. Uniting this COOH-group (carboxyl) to the methyl group, and expanding these radicles, we have the fully-dissected formula of acetic acid,



$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\overset{\overset{O}{\|}}{C}-O-H.$$

What does this formula tell us? What does it predict? Of the four hydrogen atoms, three are directly united to carbon, and one is distinguished from the others by being indirectly united to carbon by means of oxygen. We know that hydrogen, when directly united to oxygen (for example, in water) may be displaced by electro-positive elements such as metals; and we find that in acetic acid one hydrogen atom is distinguished from the others by this property. We know that hydrogen atoms in direct union with carbon (as in the hydrocarbons) may be displaced by electro-negative elements such as the halogens. This we find to occur in the case of acetic acid: there are three atoms of hydrogen which may be successively displaced by chlorine and other electro-negative atoms or groups. That these three chlorine atoms are attached to the same atom of carbon, and that therefore the three atoms of hydrogen which they have displaced are also so attached, is shown by the fact that potassium trichloracetate, when warmed with a solution of potassium hydroxide, yields chloroform ($CHCl_3$)—

$$\begin{array}{l} CCl_3 \dotplus CO.OK. \\ \;\;\;\;H \dotplus OK \end{array}$$

The same reaction with ordinary potassium acetate (a higher temperature being, however, required in this case) yields marsh gas ($CH_4$)—

$$\begin{array}{l} CH_3 \dotplus CO.OK. \\ \;\;\;\;H \dotplus OK \end{array}$$

In both these reactions the molecule is divided at the point of union of the carbon atoms. Apart from this disruption, each carbon atom retains the same atoms in combination with it after the separation which were attached to it before. In the reaction with phosphorus trichloride already referred to, the molecule of acetic acid is divided at the point of union of the hydroxyl group (OH) with the acetyl group ($CH_3.CO$). That such separations are possible without disturbing the atomic arrangement of the separated groups renders the construction of constitutional formulæ possible. But the point to be noted is that all the foregoing reactions and many others—in fact all the reactions of acetic acid—are satisfactorily explained by the constitutional formula, and are, so to speak, embodied in the formula.

A constitutional formula is thus founded on reactions and predicts reactions. In this lies its chief value. A constitutional formula which is not founded on reactions possesses a very slight value indeed. The constitutional formula of a complex mineral silicate, for example, is not an expression of the reactions of that silicate, inasmuch as the silicate has not hitherto been induced to yield any variety of reactions worth mentioning: it is merely the simplest, and perhaps the most symmetrical, way of arranging the component atoms consistently with their valency, and in accordance with certain analogies in the constitution of salts of oxygen-acids. Not even the molecular weight of the silicate is known, and this knowledge is the first step towards the construction of a constitutional formula which shall have any great value. But the beginner, who has not always the genesis of the various formulæ before his eyes, is apt to put all constitutional formulæ into one category, and to view all with equal trust or distrust according as his temperament happens to be sanguine or sceptical.

The chief opponents of constitutional formulæ are to be found among inorganic chemists. Constitutional formulæ are essentially a creation of organic chemistry. We have seen that they mainly originated in the necessity of explaining the phenomena of isomerism. Now isomerism, which is the rule in organic chemistry, is entirely the exception in inorganic chemistry. The constitutional formulæ of inorganic chemistry are thus an artificial growth: they are the result of an attempt to transplant into inorganic chemistry methods and analogies derived from organic chemistry, and it cannot be affirmed that these borrowed growths have altogether flourished in the new soil. Where the organic formulæ have guided the chemist through the labyrinths of the various classes of compounds, predicted reactions, laid down the number of possible isomerides, and shown the way to the synthesis of natural compounds so high in the scale of complexity as alizarin and indigo, the same methods applied to inorganic chemistry have led to no tangible result higher than that of checking a few doubtful formulæ by means of the laws of valency. The reasons of the failure have already been indicated. But the partial failure of constitutional formulæ in inorganic chemistry is hardly an argument against their use in organic chemistry, where they have achieved the most signal success.

Up to this point we have regarded the constitutional formula simply as a symbolic device, by means of which reactions and cases of isomerism may be expressed and predicted. The question now arises: Is it anything beyond this? A constitutional formula is primarily a certain definite arrangement of atomic symbols. Is there anything like this atomic arrangement in the molecule itself, or even anything corresponding with it?

It is in the highest degree improbable that there is anything *like* it in the molecule itself, but quite possibly there is something *corresponding with* it. That the constitutional formula cannot be like the molecule in the sense of being a picture of it is manifest from a variety of considerations. To mention one out of several: a constitutional formula represents the atoms as points connected with one another in a certain definite way by lines of attraction, without reference to any actual positions in space which these atoms may be supposed to occupy; for the sake of convenience they are represented as lying in the plane of the surface on which the formula is drawn. Now the kinetic theory of gases informs us that the atoms within the molecule are not to be conceived of as occupying their positions in a state of rest: each executes some form of vibration or rotation. This view is quite compatible with the existence of definite relations of attraction between given atoms within the molecule. To borrow an illustration from astronomy, we might in the constitutional formula of acetic acid, for instance, regard the two carbon atoms as the two suns of a double star, and the atoms directly attached to the carbon suns as planets—one with a satellite. The parts may execute their respective motions without disturbing the stability of the whole, any more than the stability of the solar system is disturbed by the motions of its parts. Now, it is evident that a constitutional formula which represents the atoms as motionless in a plane cannot be a true image of the molecule—cannot be *like* it.

That the constitutional formula, however, in some way *corresponds with* the molecule, is shown, not only by the chemical evidence which we have already discussed, but, what is more important, by a number of physical considerations. That the physical properties of a substance are dependent on the arrangement of the atoms within the molecule is evident from the fact that in isomeric compounds the melting-point, boiling-point, specific gravity, and other physical properties generally vary for each isomeride. A comparison of the physical properties of similarly-constituted compounds shows that in many cases very definite relations can be traced between constitution and physical properties.

Very important information has been gained in this way by studying the behaviour of organic compounds towards light. Thus a number of these compounds when in the liquid state, or in solution, cause the plane of a ray of polarized light, if passed through them, to turn through a certain angle. It was observed by Le Bel that all such optically active substances contained in their constitutional formulæ at least one *asymmetric* carbon atom—that is, a carbon atom united to four dissimilar atoms or groups; and an ingenious hypothesis has been put forward by Le Bel, and in greater detail by Van't Hoff, to account for this concatenation. The researches of Gladstone and Dale Landolt, Brühl, and others on the molecular refraction of organic liquids have demonstrated an intimate connexion between the refractive power of a liquid on the one hand and its constitution on the other, so that observations on the refractive power may be employed in ascertaining the constitution of such compounds; and Perkin has recently shown that the "magnetic rotatory power" of organic liquids—the power which such liquids possess, when placed in a strong magnetic field, of turning the plane of the polarized ray—may be utilized in the same manner. Again, the selective absorption which organic liquids exercise on light of different wave-lengths is closely connected with the constitution of these liquids; and the presence of certain organic radicals in the formula of a compound is manifested by certain definite absorption-bands which make their appearance in the photographed spectra of the infra-red (Abney and Festing) and of the ultra-violet (Hartley).

Other remarkable relations between constitution and physical properties are manifested in what is termed the *molecular volume* of organic liquids at their boiling-points —a subject first investigated by Kopp, and later by Thorpe, Ramsay, Lossen, and others. By the *molecular volumes* of compounds are understood the relative volumes which quantities of these compounds taken in the proportion of their molecular weight occupy. Kopp found that the molecular volume of a liquid organic compound at its boiling-point is the sum of the atomic volumes of its elements; and that, whereas the atomic volumes of carbon and hydrogen are constant, the atomic volume of oxygen varies with its mode of combination, having two distinct values: one value for an oxygen atom attached with both its affinities to the same atom of another element, and a second value for an oxygen atom attached to two different atoms.[1] Sulphur exhibits a similar definite variation in atomic volume in accordance with the mode of distribution of its affinities.

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[1] Kopp distinguished "intra-radical" and "extraradical" oxygen. The above is a re-statement of his views in terms of modern formulæ.

In all the foregoing instances we have a successful correlation of the results of physical chemistry with those obtained by the pure chemist in the deduction of constitutional formulæ. Many who withheld judgment, or even condemned, when the chemist was his own witness, may listen to him more favourably now that he is supported by the independent testimony of the physicist.

These investigations into the physical properties of organic compounds are of relatively recent date. There is little doubt that as they are extended new and important laws will be deduced. Much is to be hoped from thermo-chemistry, incoherent as many of its utterances as yet are. By following the path of physico-chemical research, chemists may even hope to arrive at a dynamical representation of the molecule which shall be as much more powerful as an instrument of research than the present merely statical constitutional formula, as that is more powerful than the empirical formula which preceded it. It is hazardous to try to fix a limit to scientific advance in any direction, but it is probable that the modern constitutional formula represents the limit to what purely chemical research can accomplish in determining the constitution of matter. Much will still have to be done by purely chemical research in working out the details of the existing system: the constitution of the more complex compounds will be ascertained on the lines of our present formulæ; new valuable natural compounds will be synthesized. But mere chemical reactions can probably never settle questions of intramolecular dynamics; in these help must come from physical chemistry. Moreover, the physical methods of research supplement the chemical methods in one important particular. By chemical methods we can never study the molecule as it actually exists. Our synthetical methods give us information concerning the molecule only at the moment of its formation; our analytical methods equally confine themselves to the moment of its destruction. The physical methods supply this want: they enable us to study the existing compound. Of these physical methods, one of the most promising, although one of the most recent, is the optical method, which has yielded results of the utmost importance both in inorganic and in organic chemistry. The ray of light which passes from the fixed star to the earth gives us information concerning the composition of the atmosphere of the fixed star; and it is perhaps not too much to hope that the ray of light which has threaded its way through and between the molecules of a compound, and has been modified by its contact with these, will, if properly interrogated, furnish some information concerning the structure of these molecules. Indeed, in the case of the rotation of the plane of polarized light by organic liquids, of their absorption spectra and their indices of refraction, this information has in a measure been obtained.

To sum up. The constitutional formula is not an ultimate expression of the whole truth as regards molecular structure. But it is certainly a very useful and convenient symbolical expression of certain aspects of the truth. We all hope that it may one day be superseded by some higher and more complete generalization. But it will be absorbed and assimilated, not rejected and contradicted, by that generalization. *Non omnis morietur.*

## *THE YALE COLLEGE MEASUREMENT OF THE PLEIADES.*[1]

THE Messrs. Repsold have established, and for the present seem likely to maintain, a practical monopoly in the construction of heliometers. That completed by them for the Observatory of Yale College in 1882 leaves so little to be desired as to show excellence not to be the exclusive result of competition. In mere size it does not indeed take the highest rank; its aperture is of only 6 inches, while that of the Oxford heliometer is of 7½; but the perfection of the arrangements adapting it to the twofold function of equatorial and micrometer, stamps it as a model not easy to be surpassed. Steel has been almost exclusively used in the mounting. Recommended as the material for the objective-cell by its quality of changing volume under variations of temperature nearly *pari passu* with glass, its employment was extended to the telescope-tube and other portions of the mechanism. The optical part of the work was done by Merz, Alvan Clark having declined the responsibility of dividing the object-lens. Its segments are separable to the extent of 2°, and through the contrivance of cylindrical slides (originally suggested by Bessel) perfect definition is preserved in all positions, giving a range of accurate measurement just six times that with a filar micrometer. (Gill, "Encyc. Brit." vol. xvi. p. 253; Fischer, *Sirius*, vol. xvii. p. 145.)

This beautiful engine of research was in 1883 placed in the already practised and skilful hands of Dr. Elkin. He lost no time in fixing upon a task suited both to test the powers of the new instrument and to employ them to the highest advantage.

The stars of the Pleiades have, from the earliest times, attracted the special notice of observers, whether savage or civilized. Hence, on the one hand, their prominence in stellar mythology all over the world; on the other, their unique interest for purposes of scientific study and comparison. They constitute an undoubted cluster; that is to say, they are really, and not simply in appearance, grouped together in space, so as to fall under the sway of prevailing mutual influences. And since there is, perhaps, no other stellar cluster so near the sun, the chance of perceptible displacements among them in a moderate lapse of time is greater than in any other similar case. Authentic data regarding them, besides, have now been so long garnered that their fruit may confidently be expected at least to begin to ripen.

Dr. Elkin determined, accordingly, to repeat the survey of the Pleiades executed by Bessel at Königsberg during about twelve years previous to 1841. Wolf and Pritchard had, it is true, been beforehand with him; but the wide scattering of the grouped stars puts the filar micrometer at a disadvantage in measuring them, producing minute errors which the arduous conditions of the problem render of serious account. The heliometer, there can be no doubt, is the special instrument for the purpose, and it was, moreover, that employed by Bessel; so that the Königsberg and Yale results are comparable in a stricter sense than any others so far obtained.

One of Bessel's fifty-three stars was omitted by Dr. Elkin as too faint for accurate determination. He added, however, seventeen stars from the Bonn *Durchmusterung*, so that his list comprised sixty-nine, down to 9·2 magnitude. Two independent triangulations were executed by him in 1884-85. For the first, four stars situated near the outskirts of the group, and marking the angles of a quadrilateral by which it was inclosed, were chosen as reference-points. The second rested upon measures of distance and position-angle outward from Alcyone ($\eta$ Tauri). Thus, two wholly unconnected sets of positions were secured, the close accordance of which testified strongly to the high quality of the entire work. They were combined, with nearly equal weights, in the final results. A fresh reduction of the Königsberg observations, necessitated by recent improvements in the value of some of the corrections employed, was the preliminary to their comparison with those made, after an interval of forty-five years, at Yale College. The conclusions thus laboriously arrived at are not devoid of significance, and appear perfectly secure, so far as they go.

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[1] "Determination of the Relative Positions of the Principal Stars in the Group of the Pleiades." By William L. Elkin. Transactions of the Astronomical Observatory of Yale University. Vol. I., Part I. (New Haven: 1887.)